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RESEARCH MEMORANDUM

TIME HISTORIES OF HORIZONTAL-TAIL LOADS, ELEVATOR LOADS, AND DEFORMATIONS ON A JET-POWERED BOMBER AIRPLANE DURING ABRUPT PITCHING MANEUVERS AT APPROXIMATELY 20,000 FEET

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TIME HISTORIES OF HORIZONTAL-TAIL LOADS, ELEVATOR LOADS, AND DEFORMATIONS ON A JET-POWERED BOMBER AIRPLANE DURING ABRUPT PITCHING MANEUVERS AT APPROXIMATELY 20,000 FEET

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SUMMARY

Time histories are presented of horizontal-tail loads, elevator loads, and deformations on a jet-powered bomber during abrupt pitching maneuvers at a pressure altitude of approximately 20,000 feet. The normal and pitching accelerations measured varied from -0.90g to 3.41g and from -0.73 to 0.80 radian per second per second, respectively, with a Mach number variation of from 0.40 to 0.75. The maximum horizontal-tail load measured was 17,250 pounds down. The maximum elevator load was 1900 pounds up. The stabilizer twisted a maximum of 0.76° leading edge down at the tip. The greatest fuselage deflection at the tail was about 1.7 inches down.

INTRODUCTION

The National Advisory Committee for Aeronautics is currently conducting a flight investigation to determine the loads and deformations on a jet-bomber type of airplane. These results may be used to check the accuracy of available methods for computing loads on the horizontal tail, and also the accuracy of the aerodynamic-center location and the zero-lift pitching moment of the wing-fuselage combination as determined from small-scale wind-tunnel measurements. For this investigation a North American B-45A airplane has been instrumented with strain-gage bridges for measurements of the loads on the horizontal tail, vertical tail, and the wing. Additional instruments were installed for measurements of the elevator and stabilizer twist and fuselage deflection.

Time histories of aerodynamic loads and deformations for the B-45A airplane during level flight, aileron rolls, pull-ups, and turns

have been presented in references 1 to 5. This paper presents time histories of horizontal-tail loads, elevator loads, stabilizer and elevator twists, and fuselage deflections during six abrupt pitching maneuvers at a pressure altitude of approximately 20,000 feet.

INSTRUMENTATION

A three-view drawing of the test airplane, with approximate locations of the strain-gage bridges and deflection-measuring devices, is given in figure 1.

Standard NACA recording instruments were used to measure airspeed, altitude, rolling, pitching, and yawing velocities, sideslip angle, control forces and positions, and accelerations. NACA optical-recording three-component accelerometers were mounted at the airplane center of gravity and at the approximate quarter-chord station of the horizontal tail at the airplane center line. The pitching acceleration was measured at the center of gravity by electrically differentiating the angular motion of the pitching-rate gyroscope. Nose-down pitching velocity and acceleration are negative.

Two booms, one at each wing tip, extending approximately 1 local chord length ahead of the leading edge contained the airspeed head and the sideslip-angle transmitter. The results of a flight calibration of the airspeed system for position error and an analysis of available data for a similar installation indicated a Mach number error of less than ±0.01 throughout the test range.

Electrical resistance strain-gage bridges were mounted on each spar near the root on both sides of the horizontal tail to measure shear and bending moment. Strain-gage bridges were also mounted on the elevator torque tube and hinge brackets to measure torque and total elevator load, respectively.

Twist bars were installed in the horizontal stabilizer to measure stabilizer twist at the tip and midsemispan stations with respect to the stabilizer root. Control-position transmitters were installed at the tip and root of the elevators and wired electrically to measure elevator twist relative to the stabilizer. The positions of the rudder, ailerons, elevators, and elevator trim tabs were measured at the inboard ends by control-position transmitters.

An optigraph mounted within the fuselage at the rear spar of the wing continuously recorded the motion of small concentrated light sources positioned in the fuselage at the front and rear spars of the horizontal tail. An additional optical arrangement was used to measure

the distortion of the optigraph mount with respect to the datum position. From this installation a time history of the structural deflection of the rear portion of the fuselage with respect to the wing rear spar was obtained.

The output from the strain-gage bridges and twist-measuring devices was recorded on two 18-channel oscillographs. A 0.1-second-time pulse was used to correlate the records of all recording instruments.

RESULTS

Aerodynamic loads and the resulting structural twists of the horizontal tail and elevators were determined for the B-45A airplane during six abrupt pitching maneuvers at a pressure altitude of approximately 20,000 feet. Also measured was the vertical bending of the fuselage at the front spar of the horizontal tail with respect to the fuselage at the rear wing spar. Time histories of horizontal-tail and elevator aerodynamic loads, stabilizer and elevator twists, fuselage deflection, normal acceleration at the center of gravity and tail, airplane normal-force coefficient, elevator angle, and the pitching velocity and acceleration are presented in figures 2 to 7. Given in table I is the airplane weight, center-of-gravity position, Mach number, elevator trim-tab position, power condition, pressure altitude, and the range of the normal and pitching accelerations for each of the maneuvers illustrated in the figures. Aerodynamic loads were determined by adding the inertia loads to the structural loads measured by the strain-gage bridges. The airplane was trimmed in the clean condition at the start of each maneuver.

The estimated accuracies of the aerodynamic loads, twists, fuselage deflection, and parameters are as follows:

Center-of-gravity normal acceleration, g units	±0.03
Total horizontal-tail aerodynamic load, pounds	±160
Each elevator aerodynamic load, pounds	±60
Elevator angle, degree	±0.25
Elevator twist (relative to stabilizer), degree	±0.07
Stabilizer twist at midsemispan, degree	±0.007
Stabilizer twist at tip, degree	±0.015
Mach number	±0.01
Fuselage deflection, inch	±0.04
Pitching velocity, radian per second	±0.003
Pitching acceleration, radian per second per second	±0.016

Buffeting was experienced only in the maneuver illustrated in figure 2 and occurred at a Mach number of 0.40 and a normal-force coefficient of 0.98. The quantities shown in the region of buffeting are mean values and do not show the oscillations produced by buffeting.

Horizontal-tail loads.- The maximum up tail load measured (fig. 2) was 7750 pounds and occurred at a Mach number of 0.40. At the time of maximum load the normal acceleration was 2.06g at the center of gravity and 2.60g at the tail, while the pitching acceleration was -0.44 radian per second per second. The maximum down load measured (fig. 7) was 17,250 pounds at a Mach number of 0.75. The normal acceleration at the time was -0.80g at the center of gravity and -1.27g at the tail. The corresponding pitching acceleration was 0.22 radian per second per second.

The maximum up loads for each maneuver occurred near the start of the push-down portion while maximum down loads occurred as the controls were reversed and the pull-up portion of the maneuver was started.

Elevator loads and elevator positions.- The maximum up load measured on the elevator (fig. 7) was 1900 pounds and occurred on the left elevator at a Mach number of 0.75 when the elevator was deflected 3.7° down. The maximum down load (fig. 5) was 650 pounds also on the left elevator at a Mach number of 0.71 with the elevator deflected 1.0° up. In most cases the elevator peak loads are reached just after the peak horizontal-tail loads.

The left-elevator position at the root was more down than the right elevator for all maneuvers with a maximum measured difference of about 2°. The maximum elevator rate occurred for the pull-up maneuver shown in figure 2 and was about 33° per second.

Stabilizer and elevator twist.- The maximum stabilizer leading-edge-up twist (fig. 2) occurred on the right stabilizer at 0.40 Mach number and was 0.21° and 0.09° at the tip and midsemispan, respectively. The maximum leading-edge-down twist (fig. 7) was on the left stabilizer at a Mach number of 0.75 and was 0.76° and 0.37° at the tip and midsemispan, respectively. In all maneuvers the right stabilizer was twisted more leading edge up than the left stabilizer.

The elevators have a built-in twist of 1.2° trailing edge up at the tip, distributed parabolically from the root. The elevator twist on the whole varied directly as the elevator load and increased trailing edge down as the elevator load increased down.

The nonsimilarity of the left- and right-elevator twists may be attributed partly to the estimated accuracy of the twist, $\pm 0.07^{\circ}$. Interruptions in the elevator twist traces were due to temporary faulty instrument operation and to a sequent power-off signal occurring at critical points.

Fuselage deflection.- In level flight the fuselage deflection increased downward with increasing Mach number. The fuselage deflection is a function of the tail load, normal acceleration of the airplane, and the pitching acceleration. In the maneuvers illustrated in figures 2 to 7 the fuselage deflection depended upon whether the

bending moment due to the horizontal-tail load was greater or less than the bending moment due to the fuselage inertia-load distribution. The moment due to tail load was greater at the start of the maneuvers and at the time the controls were reversed.

The maximum fuselage vertical deflection measured (fig. 5) was about 1.7 inches down. At the time of maximum deflection the tail load was 1300 pounds up, the normal tail acceleration was 3.7g, and the pitching acceleration was 0.72 radian per second per second nose down.

Pitching acceleration.- The maximum pitching acceleration measured (fig. 2) was 0.80 radian per second per second and was associated with an elevator rate of about 33° per second and an elevator throw of about 5.9°. The corresponding change in tail load was 4700 pounds.

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TABLE I

SUMMARY OF FLIGHT CONDITIONS

Figure	Airplane weight (lb)	Center-of-gravity position (percent M.A.C.)	Mach number (a)	Pressure altitude (ft)	Power condition (percent maximum rpm)	Elevator-trim-tab position, airplane nose up +; nose down - (deg)	Center-of-gravity normal-acceleration range (g units)	Center-of-gravity pitching acceleration range (radians/sec^2)
2	62,500	28.4	0.40	19,700	85	+8.0	-0.89 to 2.06	-0.56 to 0.80
3	60,800	28.4	0.50	19,800	85	+2.5	-0.68 to 2.56	-0.68 to 0.59
4	59,700	28.3	0.61	20,100	93	0	-0.80 to 2.95	-0.69 to 0.79
5	57,900	28.6	0.71	19,700	99	-2.5	-0.58 to 3.41	-0.73 to 0.60
6	57,400	28.9	0.73	20,000	100	-3.0	-0.81 to 2.22	-0.50 to 0.28
7	57,000	29.1	0.75	19,400	100	-3.0	-0.90 to 1.72	-0.46 to 0.41

[a]Mach number remains constant throughout maneuver within the estimated accuracy.

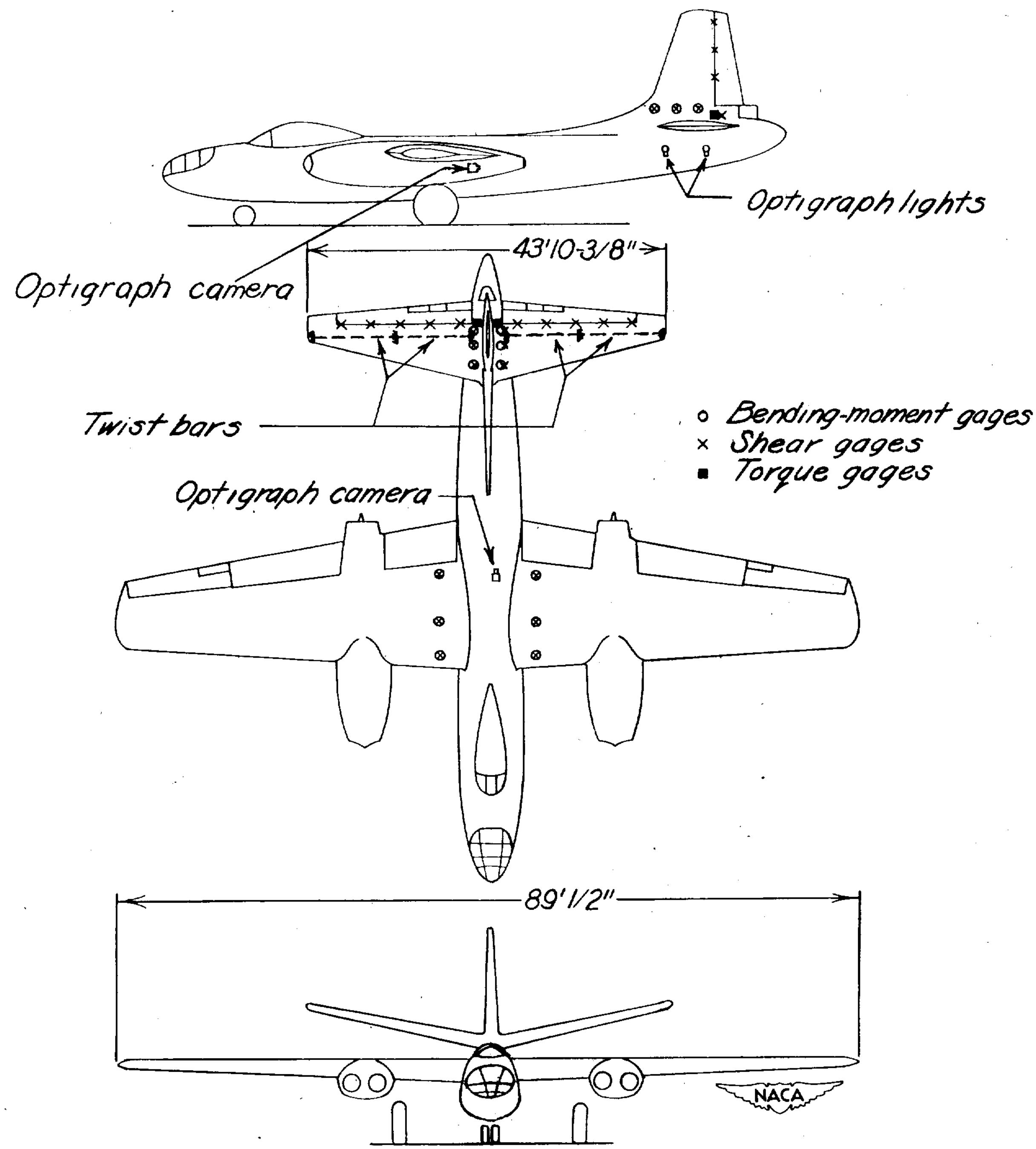


Figure 1.- Three-view drawing of test airplane showing approximate locations of strain-gage bridges and deflection-measuring devices.

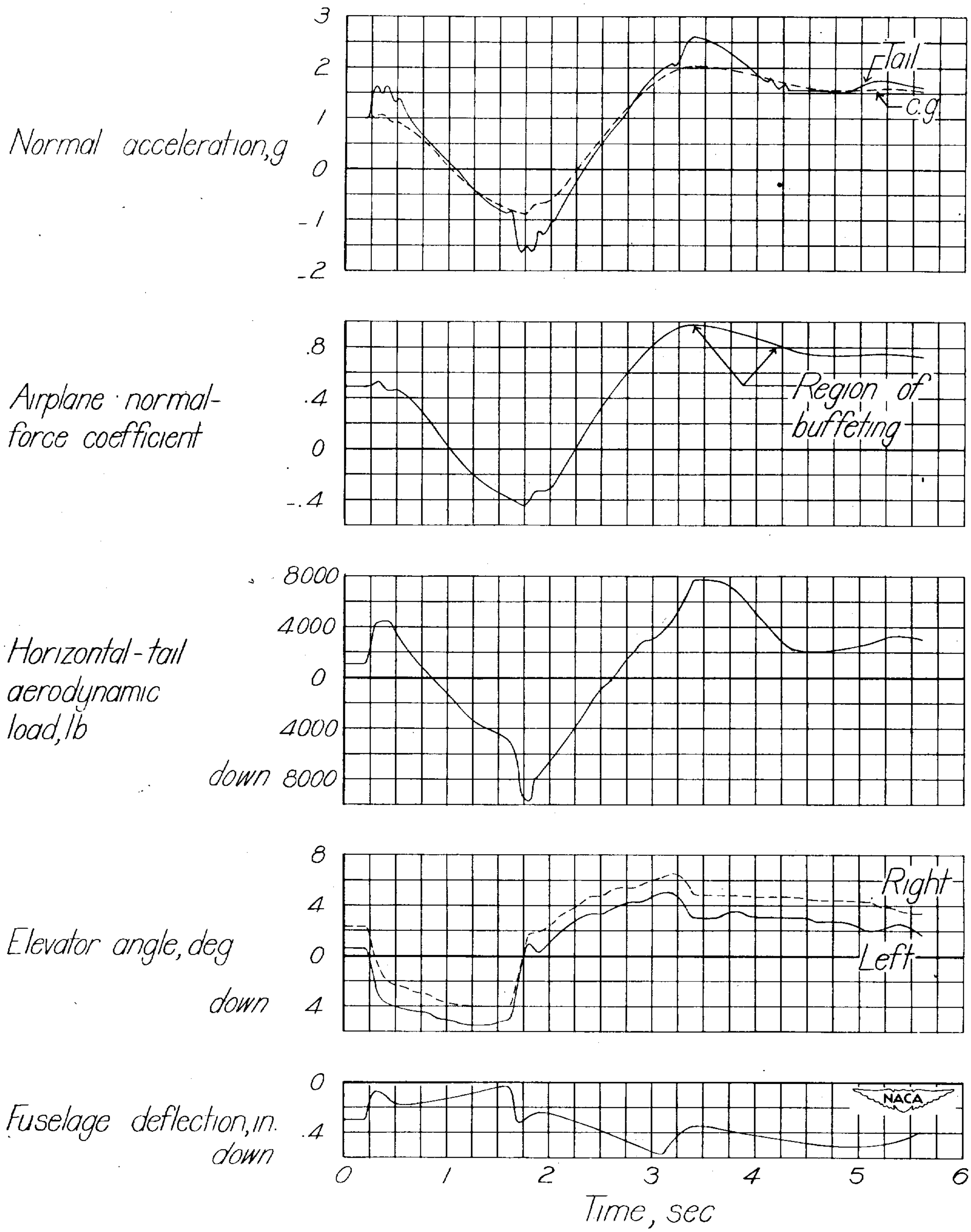


Figure 2.- Time histories of various quantities during an abrupt pitching maneuver. Pressure altitude, 19,700 feet; Mach number, 0.40; airplane weight, 62,500 pounds; center of gravity is at 28.4 percent mean aerodynamic chord; elevator trim tabs, 8.0° airplane nose up.

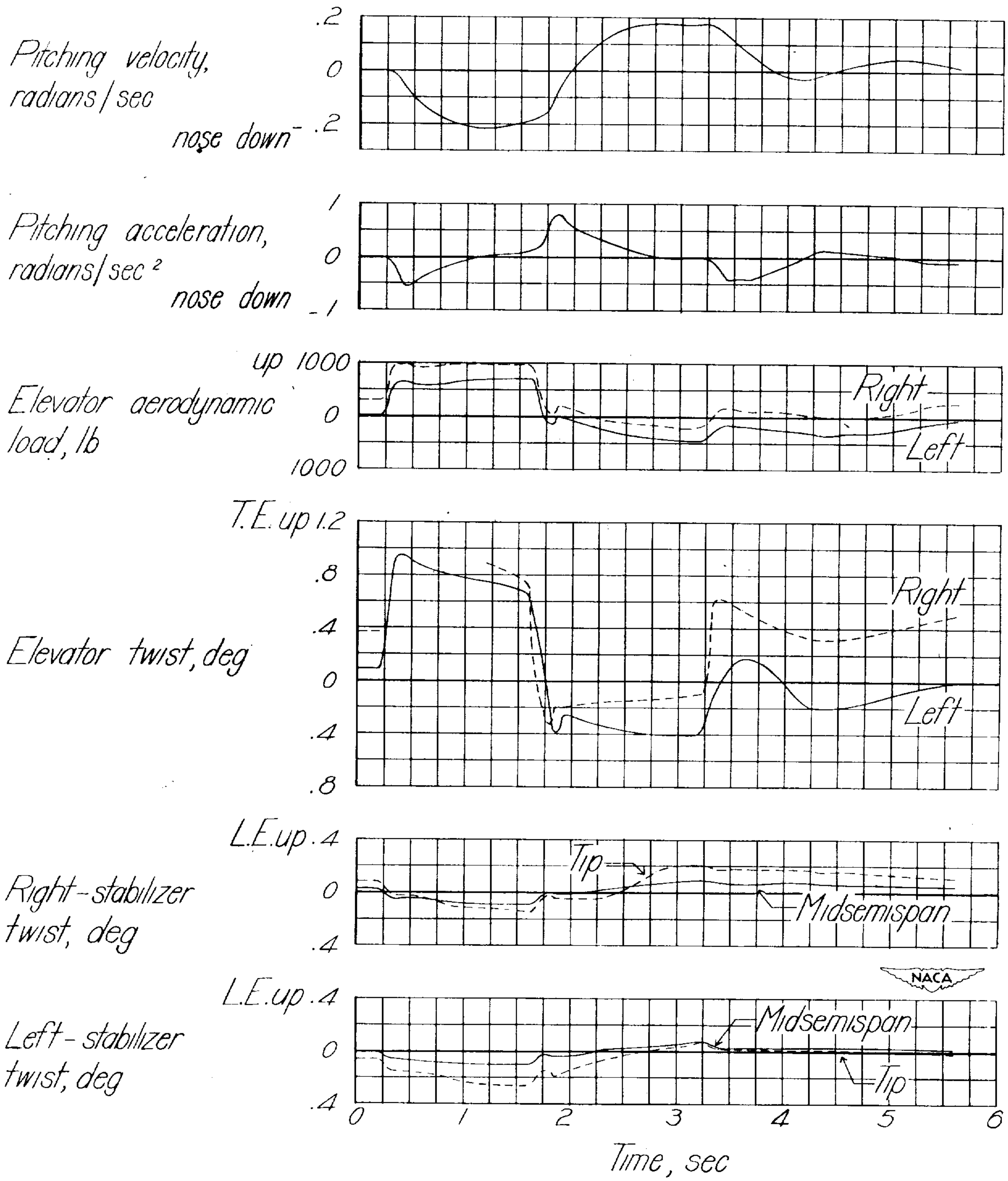


Figure 2.- Concluded.

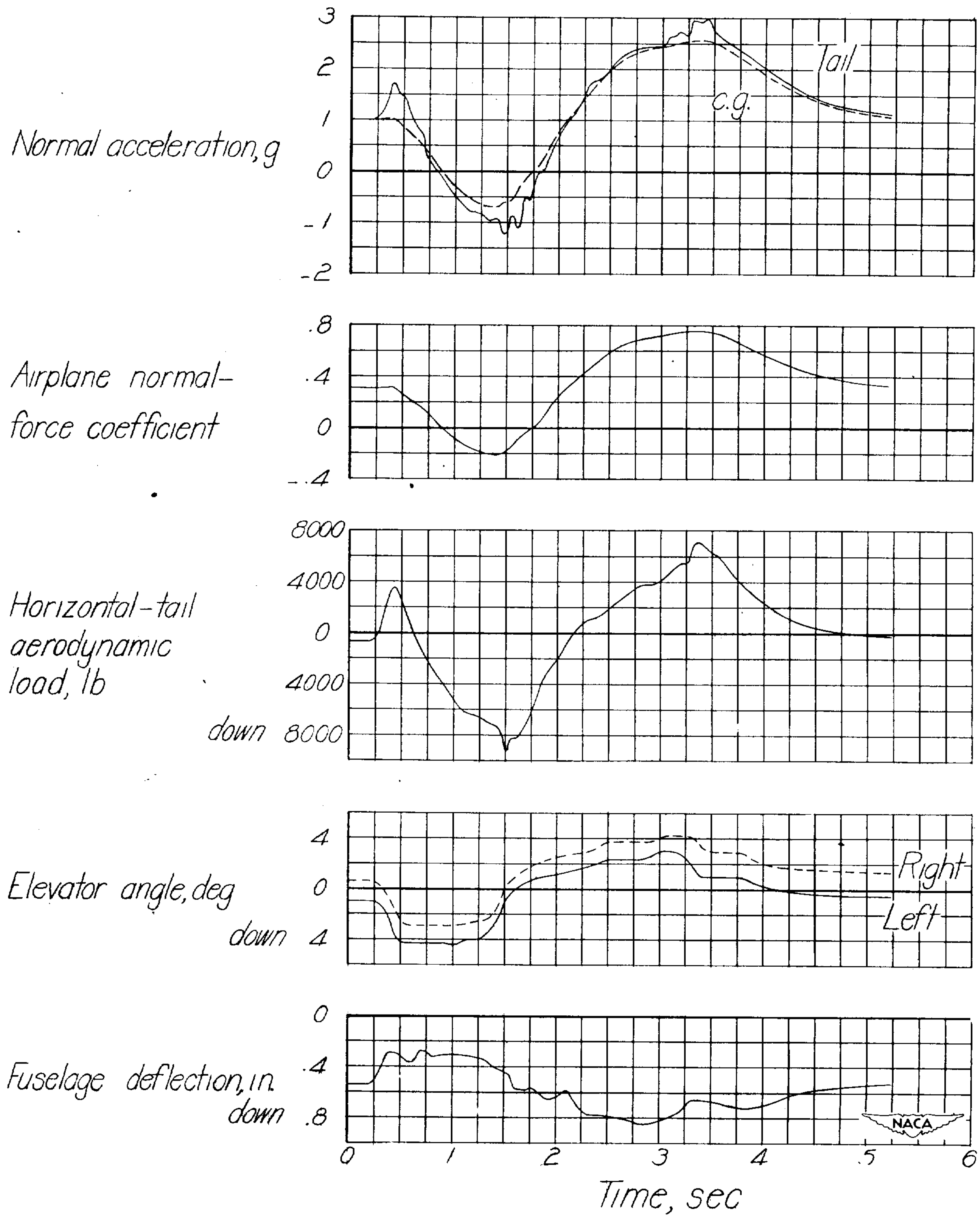
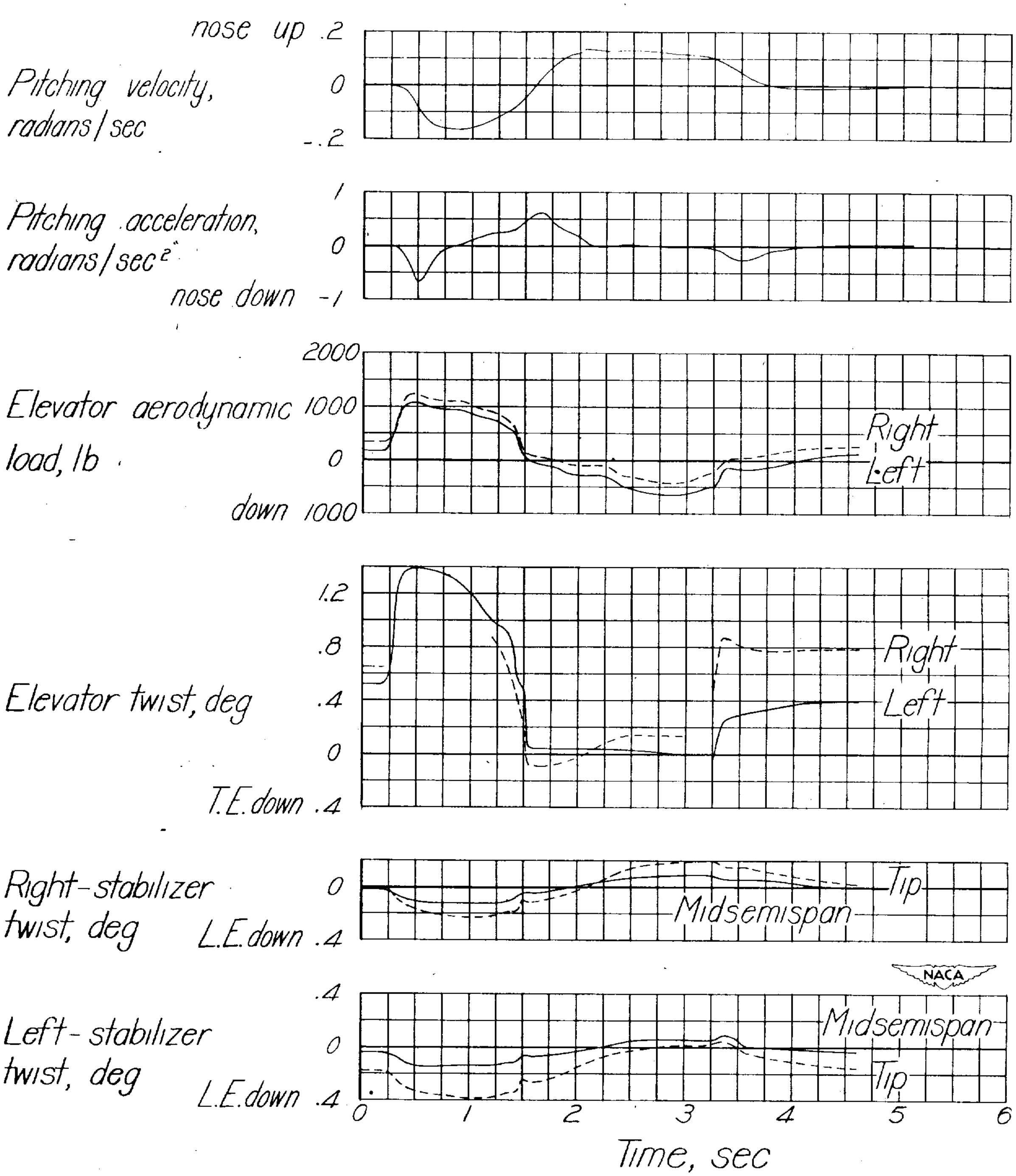


Figure 3.- Time histories of various quantities during an abrupt pitching maneuver. Pressure altitude, 19,800 feet; Mach number, 0.50; airplane weight, 60,800 pounds; center of gravity is at 28.4 percent mean aerodynamic chord; elevator trim tabs, 2.5° airplane nose up.



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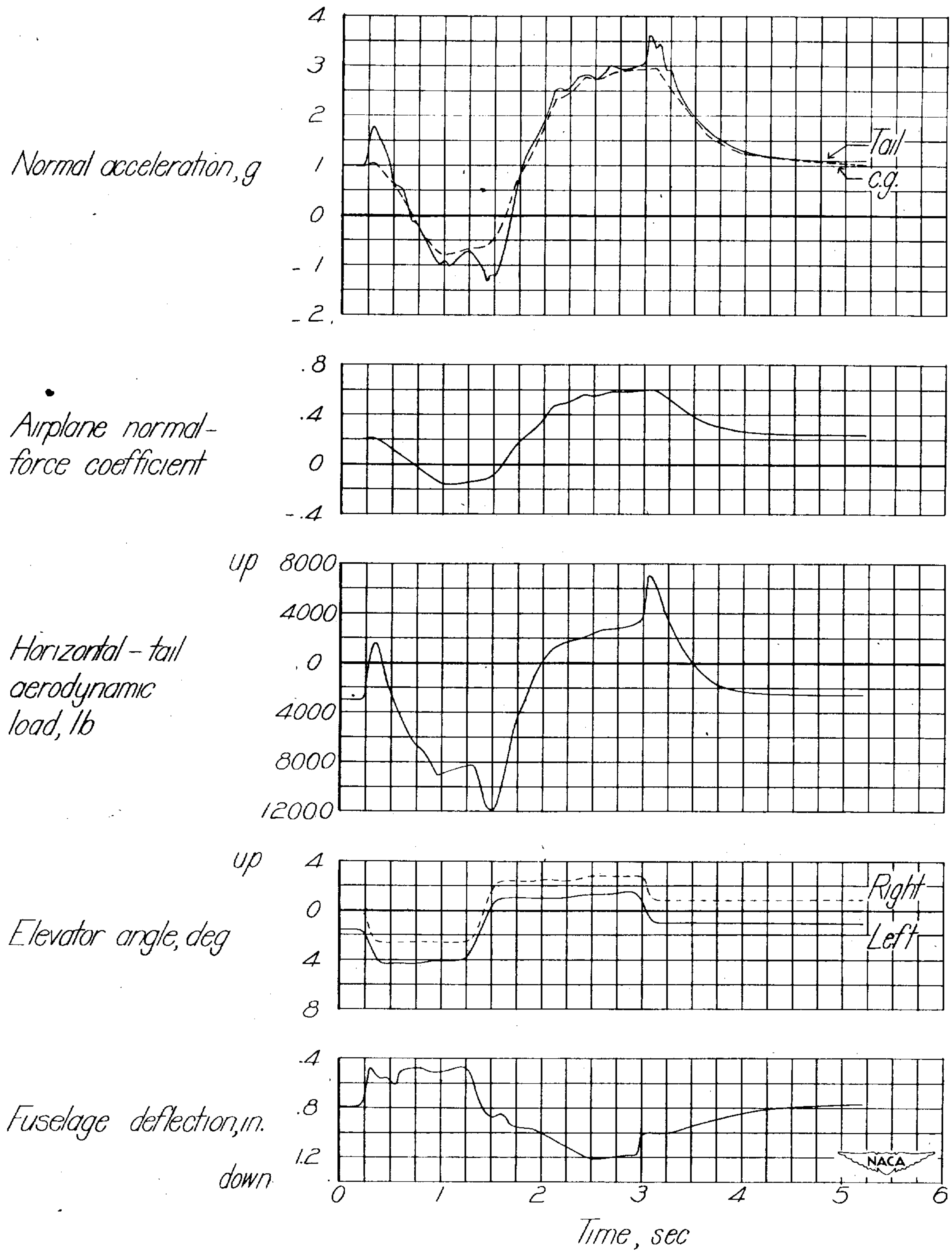


Figure 4.- Time histories of various quantities during an abrupt pitching maneuver. Pressure altitude, 20,100 feet; Mach number, 0.61; airplane weight, 59,700 pounds; center of gravity is at 28.3 percent mean aerodynamic chord; elevator trim tabs, 0°.

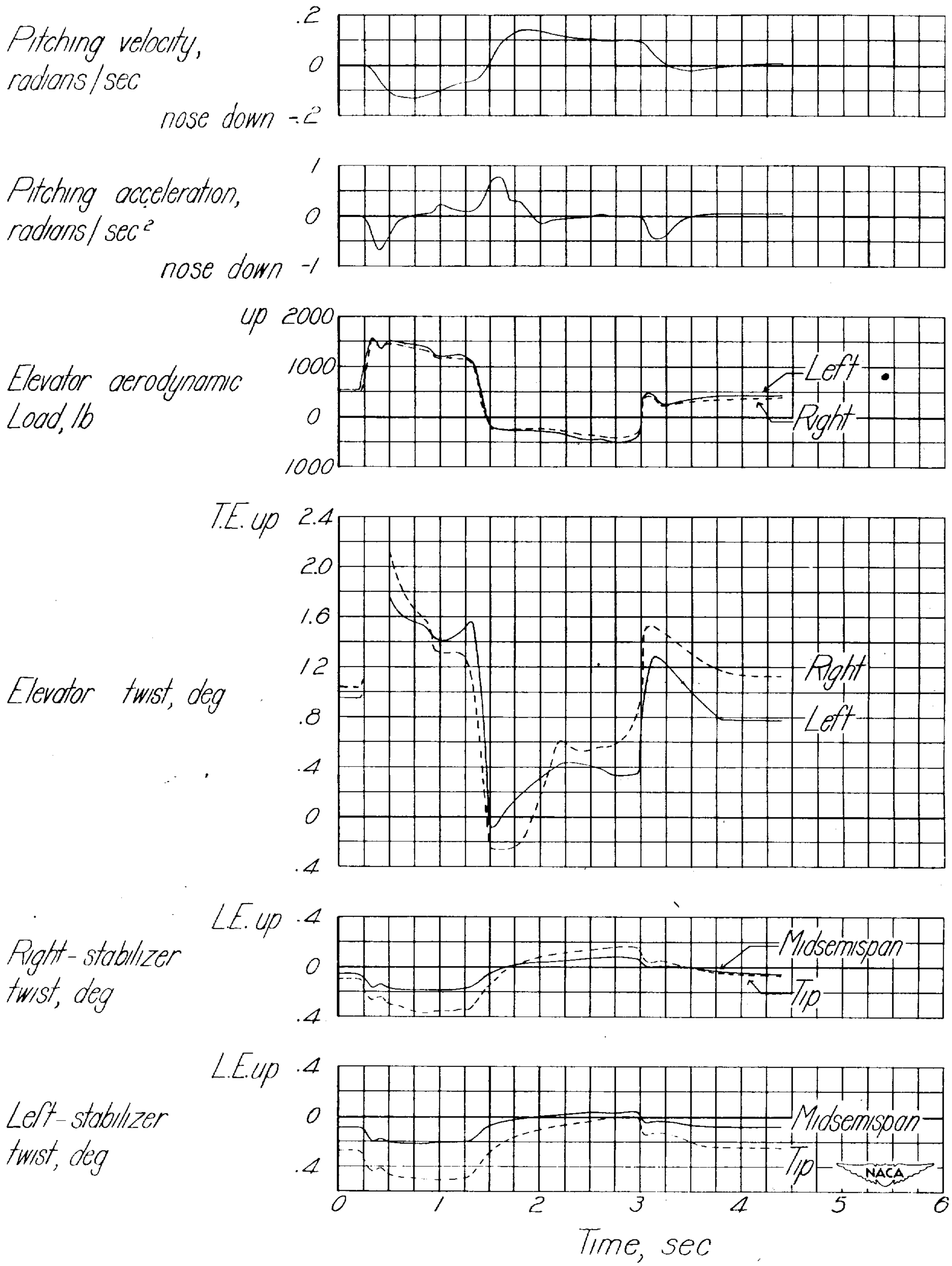


Figure 4.- Concluded.

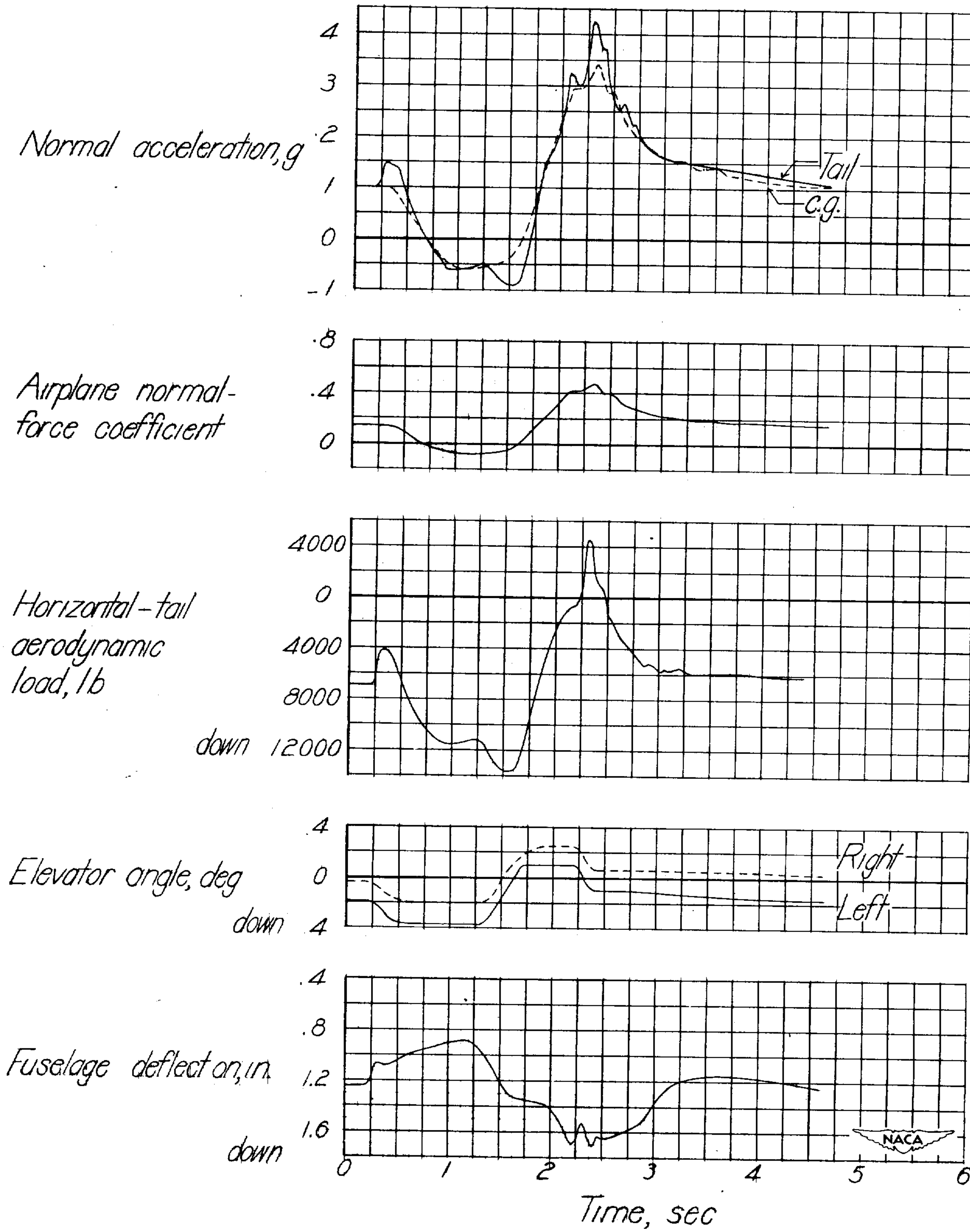
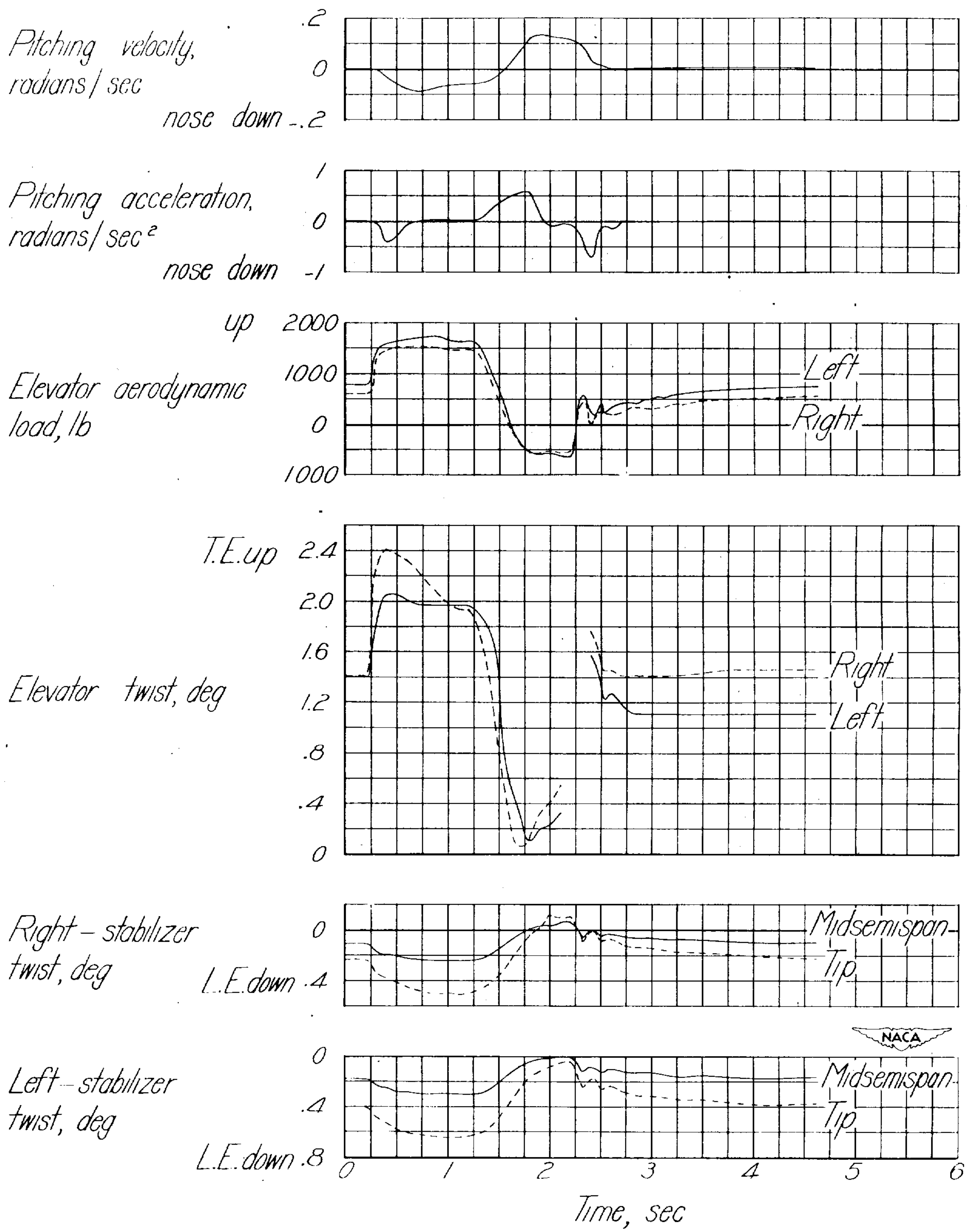


Figure 5.- Time histories of various quantities during an abrupt pitching maneuver. Pressure altitude, 19,700 feet; Mach number, 0.71; airplane weight, 57,900 pounds; center of gravity is at 28.6 percent mean aerodynamic chord; elevator trim tabs, 2.5° airplane nose down.



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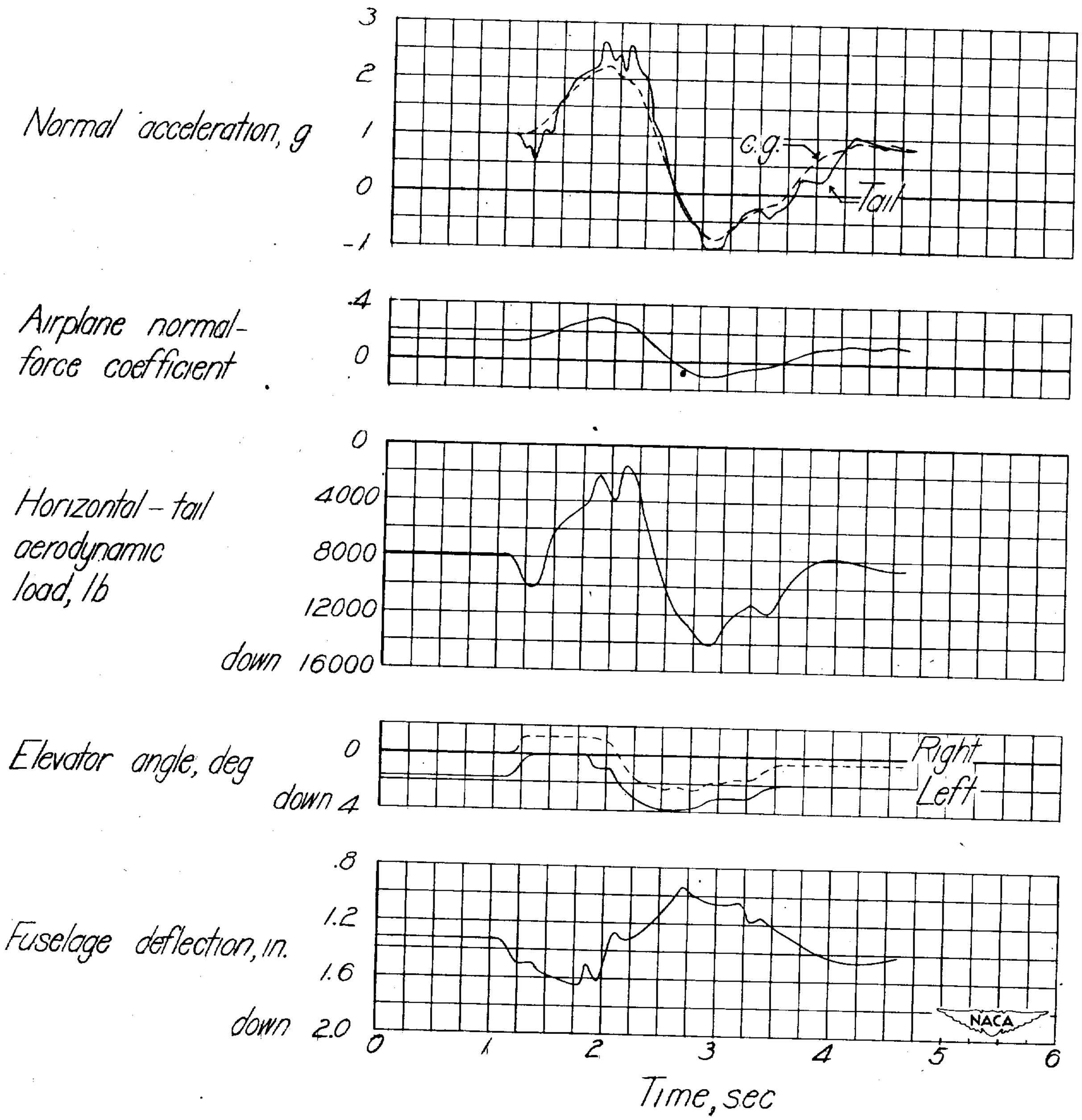

Figure 6.- Time histories of various quantities during an abrupt pitching maneuver. Pressure altitude, 20,000 feet; Mach number, 0.73; airplane weight, 57,400 pounds; center of gravity is at 28.9 percent mean aerodynamic chord; elevator trim tabs, 3.0° airplane nose down.

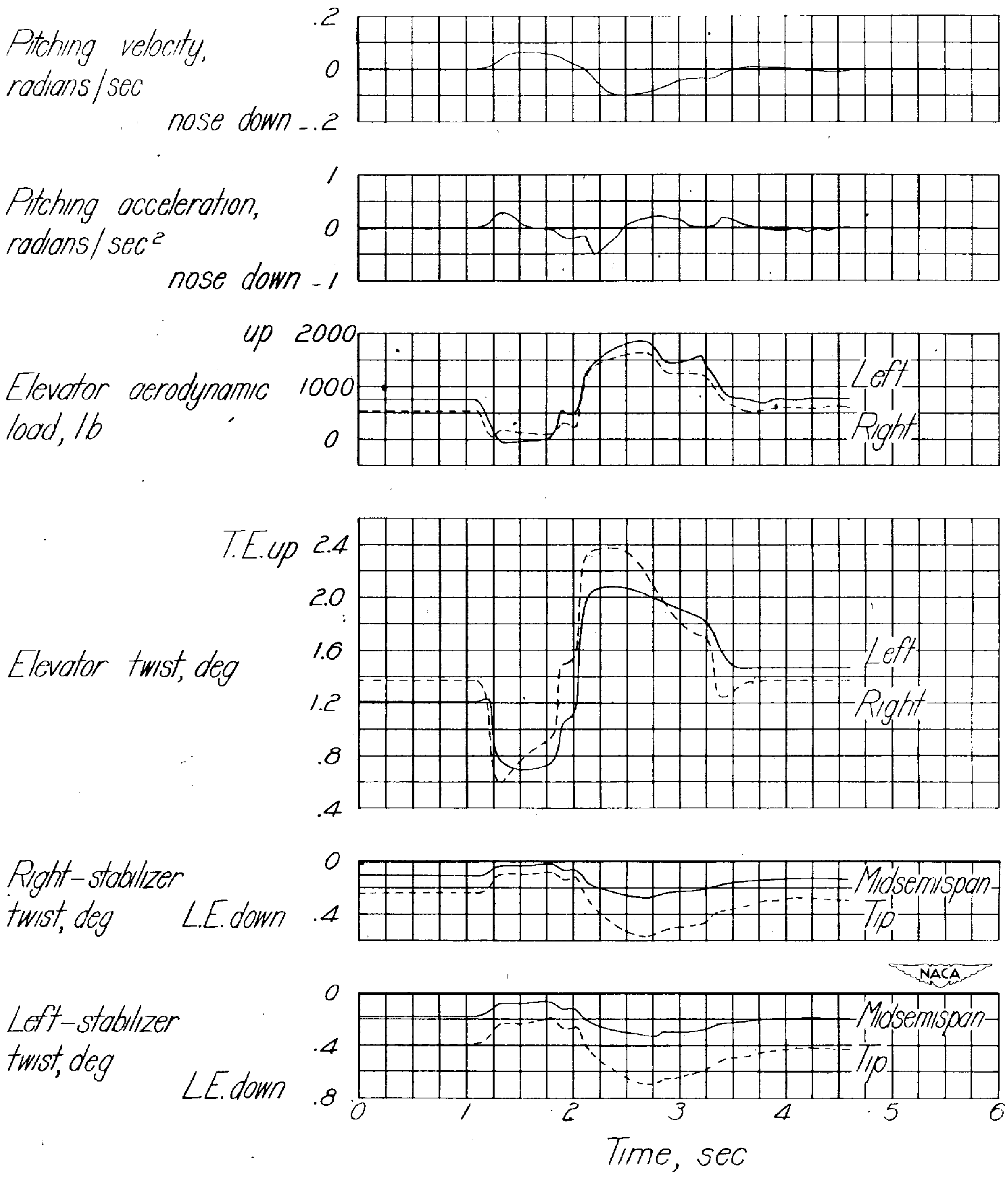

Figure 6.- Concluded.

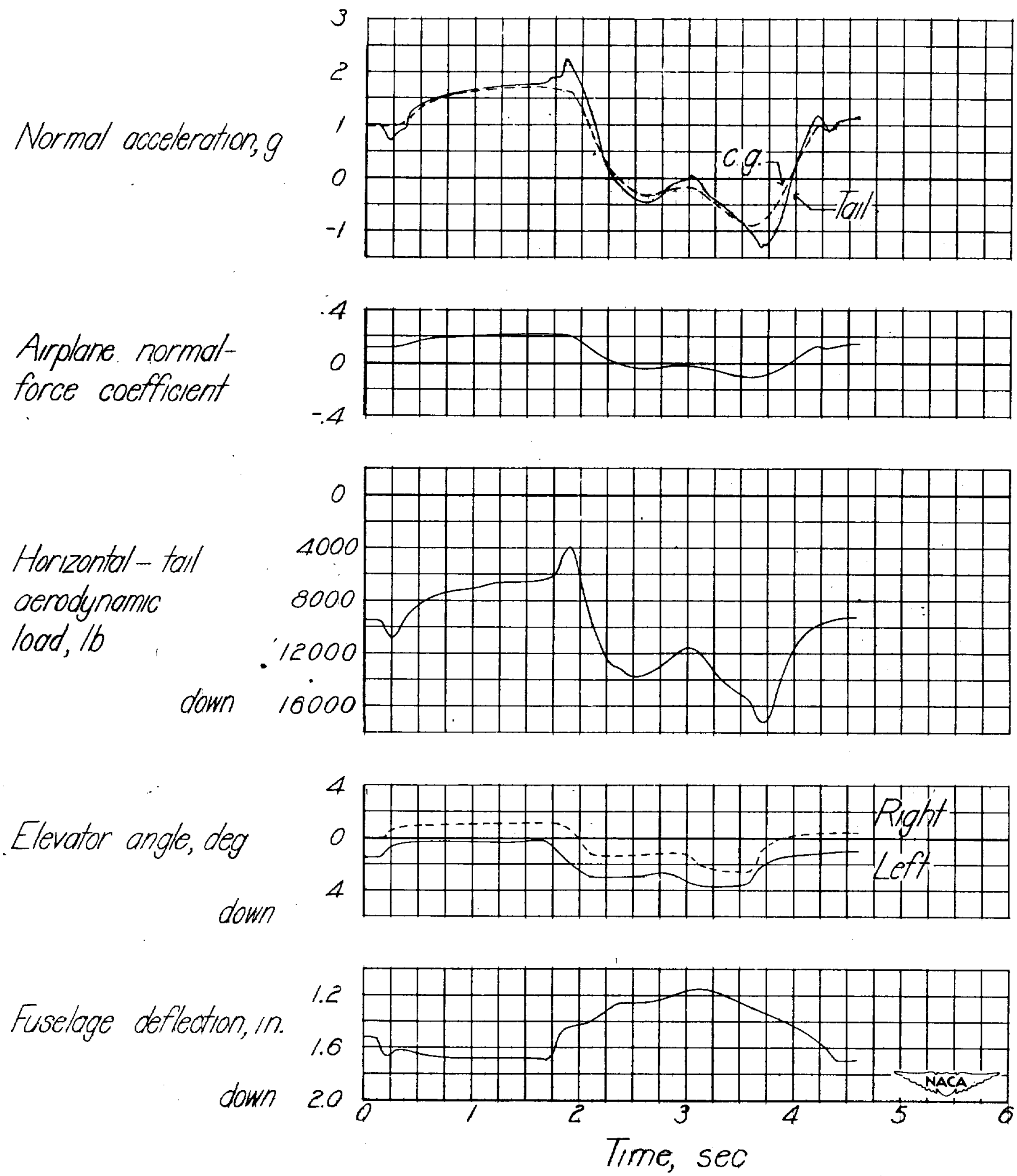

Figure 7.- Time histories of various quantities during an abrupt pitching maneuver. Pressure altitude, 19,400 feet; Mach number, 0.75; airplane weight, 57,000 pounds; center of gravity is at 29.1 percent mean aerodynamic chord; elevator trim tabs, 3.0° airplane nose down.

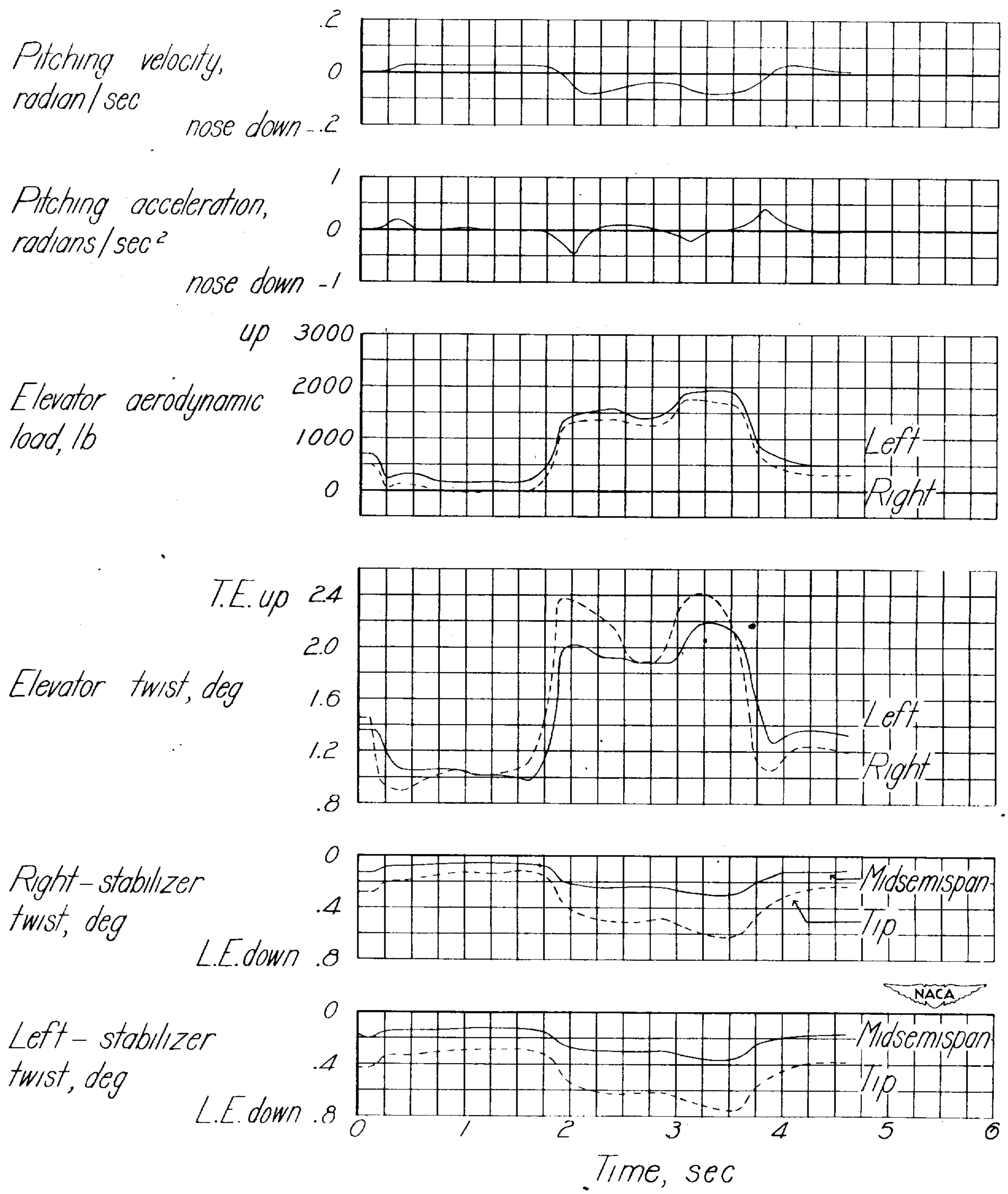

Figure 7.- Concluded.